Modeling the Effect of Rigidity in Organizational Structure on Organizational Self-Renewal and Knowledge Diffusion: A Theoretical Framework

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ABSTRACT

Combining and Extending the concepts of fluid viscosity, system dynamics and Cobb-Douglas production function, an attempt was made to propose a theoretical framework that models the effect of organizational structure on organizational self-renewal and knowledge diffusion. It was showed that rigidity in organizational structure creates an organizational viscosity (due to vertical layers of management) and conflict of interest (between functional divisions), that affects both the self-renewal exercise and Knowledge Diffusion, which are the two most integral aspects of staying competitive in volatile business environment. It was illustrated that with the increase in the rigidity of the organizational structure causes decrease in its self-renewal exercise and diffusion of knowledge. Ironically, the model also shows that absence of any structure also has a negative impact on organizational self-renewal and knowledge diffusion. Based on its self-renewal capability organizations are categorized here, as innovators, adapters (both early and late), laggards and virtual innovators. The model explained, graphically, how knowledge diffusion decreases the time to innovate.

KEY WORDS

Knowledge Carriers (KC), Organizational Viscosity, Damping Ratio, Organization Self-Renewal, Steady State, Knowledge Diffusion

1. INTRODUCTION

Rigidity in the organizational structure has a noteworthy effect on both, organizational self-renewal exercise as well as diffusion of knowledge. While this effect has been observed and

explicated in academic literature, popular press and business periodicals, little has been done[1] to create a model that can exhibit this or that can explain the phenomena. An attempt was made to integrate concepts from theoretical physics, system sciences and integral calculus to develop a conceptual framework of organizational structure its self-renewal, and diffusion of knowledge.

With the implicit recognition that rigidity in organizational structure affects both knowledge diffusion and organizational self-renewal, there has been a tendency towards making an organization completely flat in the light of making it more competitive and knowledge-intensive. The proposed framework appreciates that rigid structure has a negative impact on organizational self renewal and diffusion of knowledge, but a completely flat organization does not have the necessary social capital to strike a balance striking a balance between the knowledge acquisition processes and to solve the organizational issues and challenges within reasonable time.

The impact of organizational structure on self-renewal and knowledge diffusion was studied in the light of the freedom of movements allowed to the Knowledge carriers (KC)[2] in an organizational setting. Varying levels of rigidity of organizational structures affects the movements of knowledge carriers, creating four types of organizations in terms of their varying capabilities to cope with changing business environments. These types of organizations are: *Innovators; Adapters, both early and late; Laggards;* and *Virtual Innovators.* The first three of these four types of organization are analogous to the category of technology adopters explicated by Moore (1991). He based his work on the level with which firms adopt new technology. A similar structure was proposed here, based on an organizations varying ability to change and adapt to volatile environmental conditions.

Innovators are those, who change the rules of the game as explicated by Hamel and Prahalad (2002). These organizations work very hard in developing core-competencies for instance Honda with engines, Dell's Just in Time Supply Chain management, Wall Mart in retailing and Microsoft's de-verticalization of the computer industry. The model shows that these organizations create a steady state, a level in which sustainable competitive advantage results. Their rate of *self renewal* (Van den Bosch, Volberda, and Lewin, 2004) is remarkably high.

Next, are the *adapters (early and late)*, who adapt themselves to a changing environment to sustain competitive advantage. Their rate of adaptation to changing environmental condition is more than often dependent on the cultural inertia, high exit barriers due to inherent organizational

[1] As revealed through our search, which surely is not exhaustive.
[2] Please refer to section 3. Model.

structure. While an early adapter thrives to adapt, a late adapter usually finds it difficult (Burgelman, Maidique, and Wheelwright, 2001). Intel Corporation's coming out of the DRAM manufacturing due to severe industrial competition from Japanese is an example of fast adaptation. Other examples are airlines joining the Sabre Network, Border's Books joining the Amazon.com network to boost sales. Thirdly, there are the *laggards*, the organizations that adaptation either fruitless or impossible to attain.

A *fourth* category of firm is also added to the list; the ones who otherwise are great innovators but never get any success in finding a market for it. Their innovations thus result in no success. These firms are called, v*irtual Innovators*. This happens when organization fails in striking a balance between the knowledge acquisition processes and to solve the organizational issues and challenges within reasonable time. *Virtual Innovators* and *Laggards* never reach a stage of sustained competitive advantage.

This paper is the first of its kind that makes an attempt to conceptualize and propose a theoretical framework exhibiting how the internal features or an organization (its structure) facilitate or hinder its competitiveness (self renewal and Knowledge Diffusion) in a volatile environment conditions. The remainder of this paper proceeds as follows. Section 2 presents the literature pertaining to organizational structure, organizational self-renewal and knowledge diffusion. In Section 3 the model is presented with interpretation. It begins with defining Knowledge Carriers (KC) followed by explaining how movements of KC are affected with the increase in the rigidity of organizational structure. This was explained from the behavior of fluid viscosity. In the next section, organizational self-renewal was elucidated from the standpoint of damping ratio created by the rigidity in organizational structure on the movements of KC. In its interpretations firms are categorized as innovators, adapters, laggards and virtual innovators based on the level value of the damping ratio. Lastly, knowledge diffusion was modeled after the *Cobb-Douglas* productivity function, which productivity was considered to be Knowledge productivity. It was shown how damping ration affects the knowledge diffusion.

2. LITERATURE REVIEW

Organizational Structure

In a very recent study Chen (2004) examined the effects of knowledge attribute, alliance characteristics, and firm's absorptive capacity on the performance of knowledge transfer. His findings suggest that that knowledge transfer performance is positively affected by the explicitness of knowledge and firm's absorptive capacity and that trust and adjustment have positive effects while *conflict* possesses a curvilinear effect on knowledge transfer performance.

Authors in the field of management (Simon, 1960; Benjamin, 1995; Cooke and Slack, 1991; Daft, 1993; Wilson and Rosenfield, 1993; Reusser, Hare, and Pahl-Wostl, 2004; Pence, Dilts and Mahaffey, 2003) have long recognized that Organizational competitiveness, which depends on its ability to self renew itself against a vastly volatile environment decreases with the vertical reporting structure and bureaucracy that result in lack of interface between decision makers and the external receptors. External receptors such as salesmen and engineers are the first to get exposed to the symptoms of a Strategic Inflection Point (Grove, 1996).

Damanpour (1991) and Hage (1999) mentioned centralization had a robust and negative relationship with innovation. Aoki (1990) mentioned that the tendency towards the delegation of decision making to the lower levels of the organizational hierarchies, where economically useful on-spot information is available, as well as non-hierarchical communication among operating units, is becoming a more discernible phenomenon on a worldwide scale. Ellis (2003) mentioned competitive organizations in response to technological innovation and extreme volatile environmental conditions are increasingly becoming horizontal in their reporting structure and reduced the levels of management between the CEO and the lowest levels by 25%. The author also mentioned that Information Technology has put information on everyone's figure tips equipping lower level management teams to handle decisions more effectively. Brynjolfsson & Hitt (1997), and Brynjolfsson and Mendelson (1993) correlated the benefits reaped from IT investment with the inherent organizational structure. They have argued that centralized control and bureaucracy impedes diffusion of innovation and creative thinking which are critical for IT success. Bresnahan and Greenstein (1997) mentioned that firms that require a greater degree of organizational redesign appear to adopt IT slowly.

Numerous authors (Davenport, 1998; Duncan, 1997; Koenig and Srikantaiah, n.d.; Malhotra, 1998) also indicated steps such as, restructuring, empowerment of knowledge workers, teamwork leading to collective knowledge building are steps taken by organizations to face the challenges posed by volatile business environment.

Organizational Self-Renewal

Competitive advantage results in the way organization responses to changing environmental conditions. In 1965 Emery and Trist, observed that organizational environments were changing at an ever-increasing rate, and toward an ever-changing complexity (Malhotra, 1998). Handy (1990), Huber and Glick (1993), and Malhotra (1998) mentioned that all the levels of both environmental complexity and turbulence as well as their absolute rates of growth will be significantly greater in the future than in the past and thus the environmental change is expected to be more rapid and discontinuous in nature in the future. Increasing complexity and turbulence of the external environment impose the organization with a greater demand on its self–renewal exercise and its practice of diffusion of knowledge (Hamel and Prahalad, 2002; Hamel and Getz, 2004).

Authors (Malhotra, 1998; Collin and Porras, 1999; De Geus 1997; Hall, 1997; Hygens, Baden-Fuller, Van Den Bosh, Volberda, 2001; Huber, and Glick,1993; March 1991, March 1995; Meyer and Zucker, 1987, Van den Bosch, Volberda and Lewin, 2004) indicated that successful firms are those who appreciate the environments within which the organizations work discontinuously change over time, and take the roles of either an "Innovator" or an "Early Adapter". Death of a firm as quoted by Moore (1993) is an inevitable alternative to self-renewal. Organizations that continuously adapt themselves to changing environments live beyond strategic inflection points (Grove, 1996) and enjoy long life.

Also, it has been found in the works of Collins and Porras (1999), De Geus (1997), Hall (1997); Hygens et al. (2001) and Meyer and Zucker (1989), that long-lived companies have some structural and cultural similarities. They have inductively correlated (except for Hall, 1997) the self-renewing capabilities of an organization as its ability to successfully survive, from the standpoint of processes and structures internal to the organizations. Van den Bosch, Volberda, and Lewin (2004) found certain internal traits inherent within these organizations. These include, decentralized organizations, tolerant management style, sensitivity towards the environment, and a strong sense of identity.

Co-evolutionary theory, according to Van den Bosch *et al.* (2004) recites that an organization and its environment are interdependent and they must coexist and evolve together. Combining literature on corporate longevity which concentrates on internal characteristics of long-lived firms and the co evolutionary theory that appreciates the relationship between firm and the environment, Van den Bosch *et al*. (2004) proposed that three key principles of self renewal organizations: (a) Self Renewing organizations focus on managing requisite variety by *regulating internal rates of change equal to or exceed external rate of environmental change* triggered by

customer orientation, technology innovation, industry competition, product obsoletion and so on; (b) *Self-Renewing organizations optimize self organizing* (Nonanka and Takeuchi 1995); and (c) *Self-renewal organizations synchronize concurrent exploitation and exploration* (Levin and Volberda,1999; Levinthal and March, 1993; Levinthal , 1997; and March, 1991). Thus, it can be argued that configuration of the mentioned organizational characteristics, enable a firm to continuously renew and fit itself with the changing business environment.

Knowledge Diffusion

Clearly, from a significant collection of resources it can be inferred, that there has been a steady shift in the definition of Knowledge Management (KM) from a process of acquiring, storing and structuring of information to the creation and dissemination of knowledge under an organizational setting as an enabler and driver of competitive advantage in a volatile business environment. This shift is explicitly or implicitly exhibited in the works of Short (n.d.), Mazzie (n.d.), by Barclay and Murray (1997), Peter Ducker (Short, n.d.), Srikantaiah (n.d.b, p. 16), Davenport (1998), Dalrymple (n.d), Shelfer (n.d.), and Koenig (n.d.).

The reason for this shift could be attributed to appreciation of Information Systems as a Socio-Technical System (Alter, 1996; Fernandes, 1997; Galliers, & Baets, 1998), incorporation of concepts like intellectual capital, social capital in the core definition of KM (Srikantaiah, n.d.b ; Short, n.d.; Alavi,1997, Sahasrabudhe, n.d.), tremendous decrease in hardware cost associated with the use of Internet to set up corporate networks at an extremely lower cost (Duncan, 1997; Brynjolffson and Mendelson, 1997; Gulati, Sawhney, and Paoni, 2002) and lastly the shift of computing technology from their traditional role in the back office to supporting the day to day activities of line workers and managers, particularly those involved in knowledge work (Brynjolfsson and Hitt, 1998, Gulati *et al*.). Both the decrease in cost and increase in innovation emerged the awareness of richness and reach of knowledge that can be harnessed through KM systems.

Researchers showed a positive link between organization self-renewal with diffusion of knowledge. Seiloff (1999) and Finneran (2001) has pointed out that the critical success factor in the implementation of Knowledge Management is the creation of a cultural environment that encourages diffusion of knowledge. Koenig and Srikantaiah (n.d) mentioned that in order to achieve the maximum benefits from KM an organization must create a culture that fosters learning and transform itself into a learning organization. Learning organization is the belief that what ultimately creates and distinguishes a successful organization is its success in creating and sharing information and knowledge (Koenig and Srikantaiah, n.d.). O'Brien (2002) stated that

lasting competitive advantage could results only if firms become knowledge creating companies or learning organizations, a process for creating new knowledge, disseminating it widely throughout the company and quickly building new knowledge into their products and services.

Diffusion of Knowledge occurs when the components of a KM, consisting of Knowledge Capital, Social Capital and Infrastructure Capital depicted in Short (n.d.), work cohesively and create value as an integrated system. Short's view these components is based on the appreciation of:

1. The Changing roles of Knowledge management in creating a Fast Learning Organization (FLO) (Koenig and Srikantaiah, n.d).

2. Malhotra's (1998, n.d.) work in creating a conceptual model of KM to cope with dynamic nature of ever changing organizational environments within which it operates to a paradigm that embodies organizational processes that seek synergistic combination of data and information processing capacity of information technologies, and the creative and innovative capacity of human beings. Malhotra pointed that the information-processing view of knowledge management with it's emphasize on over specification of rules and of tasks, fails to incorporate the *double-loop learning,* a concept that was defined by Argyris (1977).

3. Koenig's (n.d), work in digging out the characteristics of information environment within a productive organization, which includes (a) easy access to information by individuals, (b) free flow of information both into and out of organizations, (c) rewards for sharing, seeking, and using new externally developed information, (d) encouragement of mobility and interpersonal contacts, (e) adapting to change, and (f) taking risks.

Zack (2003) in his paper mentioned that sustainable advantage in a competitive environment has hardly anything to do with the kinds of products a company sells and markets. He quoted " the effectiveness of KM is the degree to which knowledge is an integral part of a company is not defined by what the company sells but how it is organized." Thus, the critical success factor effective knowledge diffusion lies in the Management Support and the congeniality of the organizational culture that organizes the components of Knowledge Management collaborating with each other to achieve common and cohesive target.

Knowledge Diffusion, as per Zack (1999) enables effective management of existing knowledge and creation of new knowledge. The goal here is four fold, which are (a) ensuring that knowledge from one part of the company is applied to other parts, (b) ensure that knowledge is shared overtime, so that the company is benefited from its past experiences, (c) to make it possible for people from various parts of the organization and collaborate and create new knowledge and (d) provide opportunities and incentives for experimentation and learning.

In other words Diffusion of Knowledge enhances the core functionality of Knowledge Management as explicated by Srikantaiah, and Koenig (2000). Such functionality includes: (a) capturing organizational memory (Conklin, 1996) (b) enhancing collaboration (O' Brien 2002, Short n.d. p. 354); (c) improving productivity (McCampbell, Clare, and Gitters, 1999; Srikantaiah, n.d.b); (d) enabling and driving innovation (Malhotra, 1998; Malhotra 2000); and (e) coping with information overload (Nelke, n.d.; Agada, n.d.).

3. MODELING ORGANIZATIONAL STRUCTURE, ORGANIZATIONAL SELF-RENEWAL AND KNOWLEDGE DIFFUSION

Knowledge Carriers

From a theoretical standpoint, KM must cater to the critical issues of organizational adaptation, innovation, survival and competence in face of increasingly discontinuous environmental change. Koenig and Srikantaiah (n.d.) state that KM provides ways of reducing the constraints of existing operational management structures to improve innovation, responsiveness, competency and productivity. Based on the above enhanced role of KM *knowledge* for the purpose of this paper is defined as an attribute specific to a competitive scenario which provides an organization with detailed information, awareness, and responsiveness to aid managerial decision making in order to stay competitive in a volatile environment.

Since knowledge cannot propagate by itself, the term Knowledge Carrier is introduced who typically are either an individual who has some concerned knowledge or are the ones who first get exposed to the symptoms of a "*Strategic Inflection Point",* a term explained in Grove (1996). The group of KCs, when act coherently in an organization, forms the *social capital* (Koenig and Srikantaiah, n.d.) of the organization, that with the help of technological infrastructure and congenial management culture, adds to the Knowledge Capital. Such interaction results in awareness of a change in the external environment, whose symptoms include changing customer perceptions, technological innovations, relevance of new researches in organizational context and so forth.

Knowledge is transmitted through different forms of interaction between KCs and the other members of the organization. This mechanism of knowledge transfer initiates a process of knowledge diffusion in which knowledge persons imparts knowledge to other persons and increases the count of members in the knowledge team of the organization. *The level of diffusion of knowledge in an organization is inversely proportional to the rigidity in the organizational structure*.

Organizational Structure and Movements of Knowledge Carriers

Modeling Rigidity in Organizational Structure

In a rigid and bureaucratic organizational structure, decision makers are separated from Knowledge Carriers and Knowledge Workers by vertical layers marked by hierarchy. Even each layer is separated by distinct functional or horizontal boundaries what is termed as demarcation of Strategic Business Units (SBU). Higher the levels of management layers restricted will be the movement of KCs. Each SBU has its own interests, which may vastly differ from the organizational interest. The restriction faced by KCs due to the difference in layers of management is termed as *Organizational Viscosity or Vertical resistance.* And the resistance that KCs faced due to the *conflict of interest* between SBUs is termed as Horizontal Resistance.

In such an environment the movement of KC is restricted, as its role gets reduced to satisfy the interest needs of each group. So when a group of KC proposes something that might result in organizational changes to combat the challenges from the environments, the KCs suffer resistance from different management layers as well as several functional departments. The resistance will be more pronounced, as the pace of proposed changes is more rapid. The resistive force of this resistance tends to oppose the new positioning of KC and role played by them beyond formal layers and boundaries defined by organizational bureaucracy. More the KC moves out of the centroid from his defined zone, more will be the resistance.

Let us consider the resistance suffered by KC due to this viscosity and conflict of interest. This scenario is comparable to fluid viscosity (Feynman, Leighton, and Sands, 1989; Halliday, Resnick, and Walker, 1996; Weisstein, 2004b) when a layer of Newtonian fluid suffers a shear stress opposing any relative motion between it and its adjacent layer. The magnitude of the shear stress is proportional to the relative velocity between the adjacent fluid layers. This fluid viscosity model can be applied to organizational scenario with appropriate mapping and transformation.

Given two organizational layers separated by a knowledge difference index d[3] in the perspective of a traditional multi-layered company, holding knowledge level of one layer fixed while allowing the other layer to initiate organizational transformation at a relative speed $\mu_{0,}$ the thrust F, that will be required to keep the Knowledge Carriers pursuing knowledge acquisition and diffusion is proportional to its team size A and to $\mu_{0}.d$, suggesting a mathematical relationship as follows:

$$F/A = \eta\ (\mu_{0.}\ d).$$

[3] Based on the difference in perception between layers of management.

Here, η is a constant for the given organization and for this paper it is called *organizational viscosity*.

Given an organization with a mission plan in the direction $\hat{y}$ with a velocity μ (y), the viscous force between layers of the organizational structure is

$$F_{Viscous}(y) = \eta\, (\partial\mu / \partial y)\, dx\, dz\, \hat{y}$$

The *conflict of interest is proportional* is similar to Sheer Stress (Weisstein, 2004b). Just as this Stress is proportional to the rate of change of the sheer strain *S, it is believed that conflict of interests gets more pronounced with the rate of organizational transformation (self reneal).*

The components of S are given by the tensor

$$S_{ij} = \eta\, [(\partial\mu_i/\partial x_j) + (\partial \mu_j/\partial x_i)],$$

Where: μ_i and μ_j are the rate of transformation components.

The situation is even more complicated for a *flexible organization (Innovators or Adapters)*, i.e., one for which $\nabla.\mu \neq 0$, where $\nabla.\mu$ is the divergence[4] (Weisstein, 1999a) of the rate of transformation field. In this case, an additional term must be added for the diagonal elements S_{ij} of the conflict of interest tensor, giving

$$S_{ij} = \eta\, [(\partial\mu_i/\partial x_j)+(\partial \mu_j/\partial x_i)]+\lambda\delta_{ij}\ \nabla.\mu,$$

Where: δ_{ij} is the Kronecker delta (defined in Weisstein, 2004b) and λ is the second viscosity coefficient (Tritton 1989).

The component of the conflict of interest per unit size of organization, as defined, in the mutually orthogonal corporate parameters of the knowledge, culture and structural transformation in a small set is given by

$$F_i / A = \partial/\partial x_j\, [\{\eta\, (\partial u_i/\partial x_j) + (\partial u_j/\partial x_i)\} +\lambda\delta_{ij}\ \nabla.\ \mu\ ],$$

Where: Einstein summation (defined in Weisstein, 1999b) is used to sum over j = 1, 2, and 3. Since the variation of the viscosity coefficients with corporate parameters, is usually insignificant, they can be brought outside the derivative, so the last expression is be rephrased as

$$F / A = \eta\, \nabla^2\mu + (\eta+\lambda)\ \nabla(\nabla.\ \mu)$$

In the case of an non-flexible organization (similar to incompressible fluid as explained in Weisstein, 2004b), where $\nabla.\mu = 0$, the viscous force per unit size of the organization, simply becomes

$$F / V = \eta\, \nabla^2\mu$$

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[4] Divergence of a Vector Field *(F)*, is denoted by $\nabla.\ F$ is defined by a limit of *surface integral*
$\nabla.\ F = lim_{\ V \to 0} = (\int F.\ da) /V,$
Where the surface integral gives the value of F integrated over a closed infinitesimal boundary surface surrounding a volume element V, which is taken to size zero over a limiting process.

In a rigid and bureaucratic organization, dynamic viscosity is strongly dependent on environmental changes and may assume a form such as

$$\eta = \eta_0 e^{d/(KT)}$$

Where: d is the difference in knowledge levels of between two layers of management, k is a constant (similar to Boltzmann's Constant, expressed in Weisstein2004b), and T is a parameter proportional to absolute environmental pressure on the organization.

Dynamics of knowledge Carriers and Organizational Viscosity

There is a striking similarity between the viscosity models as applicable to an organization and the fluid materials like liquid and gas. Pressure on the container of a gas is directly proportional to the average mean free path of the gas molecules. The nature of the organization as the container of the KC plays a key role.

For flat type loosely structured organizations, the knowledge carriers can move across the organizations bringing change to combat environmental pressure and competition. More liberty is given to the KC, more is the impact created by them to initiate, adopt and adapt changes in the organization's culture and agility.

For liquid, change in environmental temperature reduces viscosity, which means less frictional force acts on a layer of liquid when it drags on an adjacent layer of the same liquid. For an equivalent organizational model, change in temperature is equivalent to the change in business environment and competition in the marketplace through mechanisms like Porter's (1980) five-force model or government policy and politics. The rise in temperature of the surroundings of the container that induces increase in the average level of momentum and energy of the fluid particles is equivalent to the competition and changes in the market place that induces an organization to achieve extra mobility and knowledge among stakeholders imparted through knowledge carriers.

This change in the environment initiates knowledge workers to increase their level of activity and logical movements. The top management actively promotes and supports the efforts of the knowledge workers and the visible commitment of top management reduces the vertically and horizontally originated resistances to the knowledge workers. The overall effect is that the knowledge workers get more freedom to move and invite changes.

Organizational Self-Renewal

Modeling Organizational Self Renewal based on the damping done to the movements of KC

The layers of management in the organization have an impact on the self renewal process demanded by the volatile and competitive environment. The rigidity in organizational structure of gives rise to an organizational viscosity, η, and a conflict of interest, whose combination prevents KCs to move freely in an organization. Free movement is absolutely necessary to collect tacit knowledge (Malhotra, 1998; Koenig and Srikantaiah, n.d.) and disseminate it across the organization among all groups discreet to a common self-renewal process of the organization. The viscous nature organization creates a damping response on the movement of KC and the overall self-renewal process of the organization towards external stimulation. Two cases of organizational self-renewal is considered here.

1. External Stimulation or change is sudden in nature and warrants an organization to react immediately. The issue here to be considered is how quickly the organization reacts to the changes. This is a characteristic successfully exhibited by the category of organization termed as innovators and early adapters.

2. External stimulation or change is a step function, remaining steady with time and the organization gets some time to reach a steady state response. The issue here is how much time the organization takes to reach a steady-state value. *Steady state* is termed as the level at which an organization reaches a stage of *sustained competitive advantage*. But reaching that steady state does not guarantee a sustained competitive advantage. Advantage results when an organization reaches there in a very short span of time. Steady state is that level where an innovator settles down, leaving a level for other organizations such as adapters or laggards to reach. The ones that reach this stage early are *the self-renewing organizations*.

Prior to coming to specific responses, the internal dynamics of organization towards the external simulation is first considered. It is considered that KC is driven by an external force E, which initiates KC's movements towards higher level of knowledge. The accelerated motion of KC is opposed by a frictional force, arising out of the organizational viscosity, proportional to the relative velocity between the adjacent layers of management where the KC resides. The KC also suffers from resistance from strategic business units others his own. This resistance is the horizontal resistance. More a KC shifts its role from defined organizational structure, more will be the resistance at vertical and horizontal level from whose domains are violated by the KC. The characteristic of the motion of KC will be in a time variant equation (adopted from Kuo, 1979)

$$(d^2x / dt^2) + 2\zeta (dx / dt) + \omega_n^2 x = 0$$

where ω_n represents un-dampened frequency of change, ζ is the damping ratio, t is the time variable, x is position variable. d^2x / dt^2 represents the driving component of *external force causing the acceleration of KC*, $2\zeta\ (dx / dt)$ is the *frictional force of vertical origin arising from organizational viscosity* and $\omega_n^2 x$ symbolizes resistance force proportional to the displacement arising from *horizontal conflict of interest*.

The equation gets transformed to $s^2 + 2\zeta\ \omega_n s + \omega_n^2 = 0$ in frequency domain. Here, s is the frequency variable. The movement of KC in the organization is controlled by feedback loop mechanism consisting of planning, organizing, executing and controlling, thereby forming a closed loop. The closed-loop transfer function of the system is determined by

$C(s)/ R(s) = \omega_n^2 / (s^2 + 2\zeta\ \omega_n s + \omega_n^2)$

Where: $C(s)$ is the output response in frequency domain, $R(s)$ is the input response in frequency domain.

For a Unit step function input R(S) = 1/s, the output response of the system is determined by tracking inverse Laplace transform of

$C(s) = \omega_n^2 / s(s^2 + 2\zeta\ \omega_n s + \omega_n^2)$,

When,

$C(t) = 1 + [\exp(-\zeta\omega_n t)/ (1-\zeta)^{0.5}] \sin [(\omega_n t (1-\zeta^2)^{0.5} - \tan^{-1} (1-\zeta^2)^{0.5} /(-\zeta)]$

For $t \geq 0$, where $C(t)$ is the output response in time domain.

Interpretation of the model with respect to four types of organizations

Depending upon the value of organizational viscosity (ζ), the movement of KC may be perpetual oscillatory ($\zeta=0$), under-damped $(0< \zeta< 1)$, critically damped $(\zeta =1)$ or over-damped ($\zeta \geq 1$). Here it is shown, how the damping ratio increases the attainment of steady state and decreases the level of overshoot[5]. It could be inferred that the *steady state does not exist in itself, but it is the level at which an innovator organization settles down*. Competitive advantage depends upon the time (t) taken by an organization to reach this steady state. The time is highest for *late adapters* and reaches infinity (∞) for *Virtual innovators*. Typically these twp categories of organizations cannot self renew itself.

[5] Overshoot is defined as the deviation of the output over the step input during a transient state. The amount of maximum overshoot is used as a measure of a relative stability of a system (Kuo, 1979).

Damping Ratio and time taken to reach steady state and Overshoot

Before discussing these cases separately, it is shown, how damping ratio affects time taken to reach steady state and overshoot. High Damping ratio is *(ζ>1)* is associated with a slow rate to attain stability. Figure 1 shows the delay in time to respond with the increase in damping ratio.

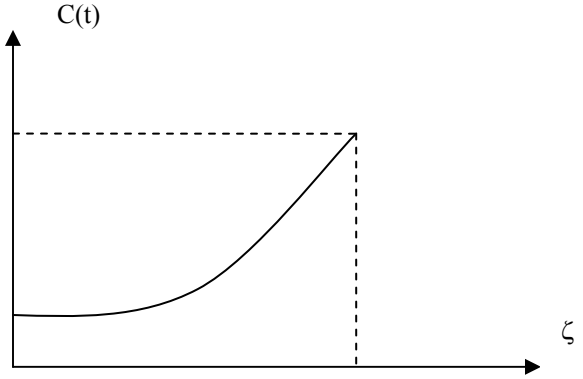

Figure1. Increase in time to respond with increasing damping ratio ζ

In figure 2 the relationship that damping ratio has with the percentage of overshoot is presented. With the increase in damping ratio percentage of overshoot drastically falls.

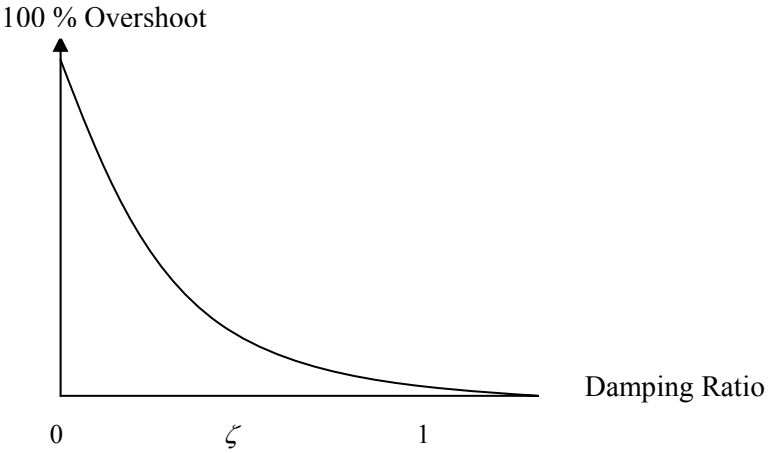

Figure 2. Increase in the Percentage of Overshoot with the Decrease in Damping Ratio, *ζ*

Innovators, Adapters (Early and Late), Laggards, Virtual Innovators with varying Damping Ratio, ζ

For interpretations of the type of organizations and their self renewal, figure 3 will be referred throughout.

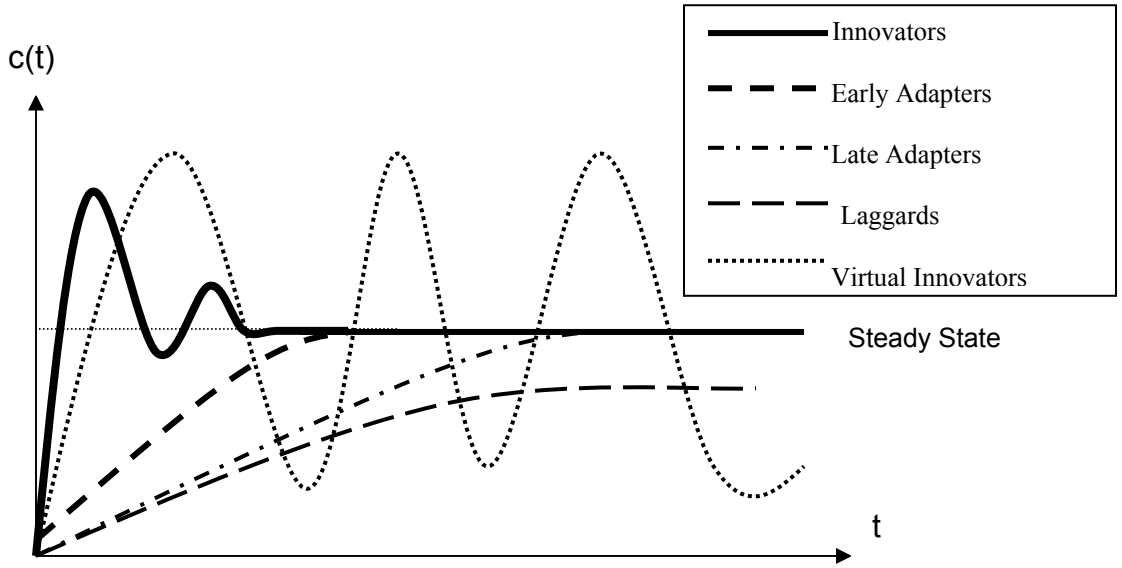

Figure 3. Types of Organizations owing to variations in Damping Ratio.

Innovators (0< ζ< 1) and Early Adapters (ζ =1) : Underdamped and Critically damped motion of Knowledge carriers. In an under damped movement of KC, that is for organizations with extremely low viscosity, internal response from the organization will rise faster. For a non-negative value of ζ nearing 0 ($\zeta = .02$), the organization will first overshoot itself, followed by few oscillations, and ultimately settle in s steady state. This entire procedure takes a very short time. Such organizations are *Innovators* and guiding all others belonging to their industry to follow them. Their Internal rate of innovation is such that they can create a benchmark for the steady state. Innovators, usually causes the external environment to change. Innovators renew itself in almost no time, as they are the creators of steady state.

Early Adapters are those whose damping ratio, ζ, is far greater than zero but less than 1. Typically $\zeta = 0.6$ is an *early adapter*. Here due to moderate damping owing to low organizational viscosity, rate of internal change within the organization is higher than that demanded by the external change. Such organizations correctly visualize a change and can renew itself by reaching the steady state (erected by the innovators) at the right time.

Late Adapters and Laggards (ζ ≥ 1), Over-Damped Movement of Knowledge Carriers. For the value of $\zeta = 1$*(known as critical damping ratio),* an organization is just about in time to

reach the steady state. Here the rate of internal change within the organization is just the lower acceptance limit demanded by the external environment.

Beyond the value of $\zeta = 1$ the organization changes its state from *late adapters* to ultimately *laggards*. An ideal laggard is characterized by $\zeta >> 1$. It never reaches the steady state or the state of sustained competitive advantage. Thus, the *rate of internal change* is far less than demanded by the *change in external environment*. For an ideal Laggard the steady state (sustained competitive advantage) is never reached, for most laggards it is too late to be translated into a competitive advantage. Thus, the *rate of internal change* is far less than demanded by the *change in external environment*. For an ideal Laggard the steady state (sustained competitive advantage) is never reached, for most laggards and late adapters, the time by which they reach the steady state is too long to be translated into a competitive advantage.

Virtual Innovators ($\zeta = 0$), No Damping. At $\zeta = 0$, there is no damping in the movement of KC, allowing them a frictionless movement. This means that knowledge workers have great ideas, but there is no formal mechanism to implement them. In such type of organizations the decision makers are aloof from the environment within which their organization resides. In such a case, there is actually no pressure on Knowledge Workers from a feedback mechanism to bring their innovations early in the market, or translate their innovations complying with business requirements. Such organizations are unable to find any market for their innovations, which otherwise are sound. These organizations never reach the stable state, as they lack management support to put it back to a level. Thus Virtual Innovators oscillate around the steady state. Their internal rate of innovation follows a totally different pattern than the external rate demanded by the environment.

Diffusion of Knowledge

Unless there is a high degree of diffusion of knowledge within the organization, the rapid rate of innovations, demanded by the volatility of the business environment will never be implemented. Diffusion of innovation is an important characteristic that helps in mapping the *internal rate of innovation* with the *external rate of environmental change*. The level of difficulty in attaining such innovations increases with the increased vertical reporting structure and bureaucracy that result in lack of interface between decision makers and the *Knowledge carriers (KC)*.

It can be plausibly inferred that an organization with rigid bureaucratic structure of control, the scope of proactive involvement of KC towards collection and diffusion of knowledge across the entire organization is extremely limited. Stiff reporting structure limits the knowledge

collection and as a result diffusion efforts of a KC, through its displacement are limited Organizations with little bureaucratic control where knowledge persons are assigned individual, independent responsibilities offer the best conducive environment for knowledge carriers to move freely to gather and disseminate knowledge among concerned stakeholders.

Diffusion of Knowledge occurs when the components of a KM, consisting of Knowledge Capital, Social Capital and Infrastructure Capital depicted in Short (n.d.), work cohesively and create value as an integrated system. The level of interaction among the three components determines the level of knowledge diffusion. For instance the role of infrastructure capital is to facilitate a knowledge capital through the deployment of technology, and the social networks available in the organization. In absence of a congenial management culture or in a bureaucratic setup or in case of a *Laggard* (damping ratio $\zeta >> 1$), the three components stay in isolation as formal entities that cannot integrate to create any value. This is depicted in figure 4. The restricted movement allowed to the KC cannot integrate the three components.

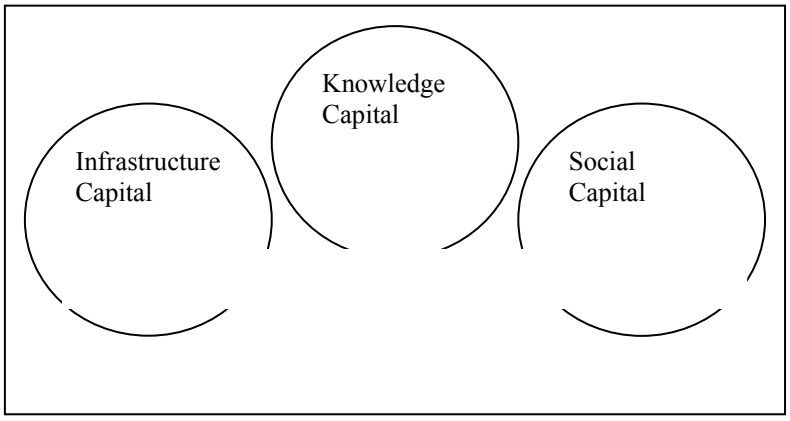

Figure4. Knowledge Diffusion for a " Laggard" that is damping ratio $\zeta >> 1$

In case of an adapter (is Damping ratio, ζ, where $0 << \zeta \leq 1$), the Knowledge diffusion depicts figure 5. Here the integration among the three components create the KM. Higher the integration greater will be the common area among the circles, leading to greater diffusion of knowledge.

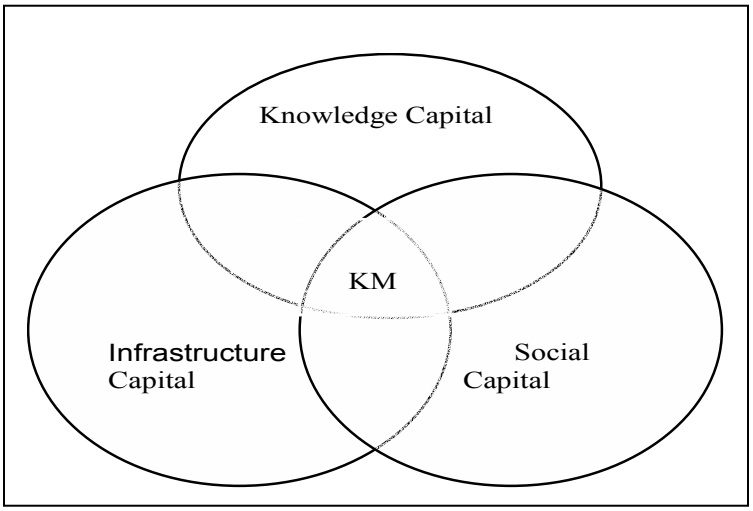

Figure 5. Knowledge Diffusion of an Adapter, that is Damping ratio, ζ, where $0<<\zeta \leq 1$

In case of an *innovator* (Damping Ratio,ζ where $0<\zeta<<1$), an organization has a structure just about to create a damping ratio to blend innovations with market requirement. In such a case it is difficult to distinguish one component from the other. They jointly diffuse as one to create value. Here the ratio of total area of the circles to the common area is 1. This is depicted in figure 6.

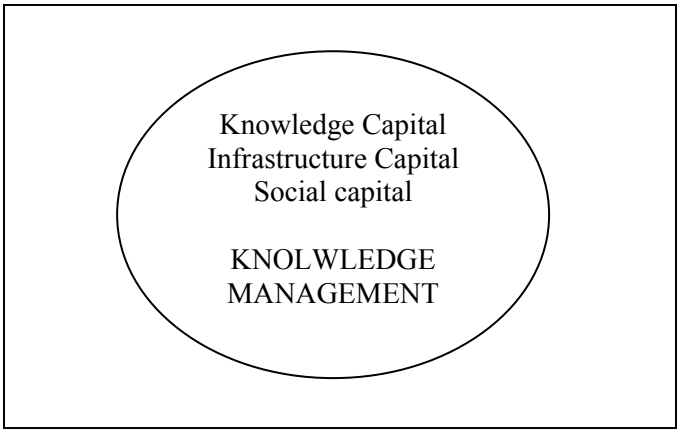

Figure6. Knowledge Diffusion in case of an Innovator, that is Damping Ratio, ζ, where $0<\zeta<<1$

In case of a *virtual Innovator* (*Damping Ratio,*ζ *where* $\zeta = 0$), there is no interaction among the knowledge workers with rest of the organization. Thus there is *no* social capital, which plays a significant role in the diffusion of knowledge.

So it can be inferred that higher the level of diffusion greater is the ratio of the Common area to total area. This ratio of areas is termed as Knowledge Diffusion Index, KD_i.

Formulating Knowledge Diffusion

Let us consider an organization with organization wide-infrastructure capital (I), and Social capital (S). Social Capital comprises of Knowledge Carriers (KC) and Labors (L, non knowledge workers). Due to the rigidity in organizational structure the interaction among these components is not enough to create an *organization wide Knowledge capital* (*G*). The knowledge capital (K) is only restricted to an particular strata. So K is a department specific Knowledge Capital. Knowledge capital within each stratum whose number ranges from *1* to *n* is represented as K_i (where $i= 1,2,3...n$).

For a particular Stratum, using Cobb-Douglas[6] production function (Brocker, 2004), we get:

$$Y_i = a\,[KC]^{\alpha}[L]^{\beta}[I]^{\gamma}[K_i]^{\lambda}$$

Where Y_i is the knowledge-based productivity of a particular stratum *i*. For the Entire organization, however the equation is,

$$Y= a\,[KC]^{\alpha}[L]^{\beta}[I]^{\gamma}[G]^{\lambda}$$

Where *Y* is the knowledge-based productivity of the entire organization and G is the *Knowledge Capital of the entire organization*.

Interaction between the Knowledge Capital and Social Capital enables knowledge capital from one stratum to migrate to another, therefore increasing the value of knowledge. Considering only two strata, 1 and 2, the increase of knowledge of strata 1 from exchange of knowledge with strata2 ($g_{1,2}$), and state 2 from increase of knowledge from strata 1 ($g_{2,1}$) respectively is given by vector equations

$(g)_{1,2}= K_1 + KD_i.\ (K_2)$ and

$(g)_{2,1}= K_2 + KD_i.\ (K_1)$

Where, *KDi* is the knowledge diffusion index, whose value increases with the intensity of intra-organizational communication that allows interaction of social capital and infrastructure capital to create organization-wide knowledge. The value of this knowledge decreases with lack of communication as explicated in Jafee, Trajtenberg and Henderson (1993).

The entire organizational (compromising two strata) Knowledge Capital would then be

$$G=g_{1,2} + g_{2,1} = K_1 + KD_i.\ (K_2) + K_2 + KD_i.\ (K_1)= K_1+K_2\,(1+KD_i)$$

To compute the value of KD_i, let $I = f_i\,(x)$ denote the functional relationship between infrastructure capital and knowledge space variable x. Similarly the functional relationship between social capital *S*, and knowledge capital *K* with Knowledge space variable, *x* is $S= f_s(x)$ and $K = f_k(x)$.

[6] Cobb-Douglas production function models how a firm combines inputs to produce outputs

The Convolution[7] between the pairs of Capital functions is,

$$I*S=\int_{-\infty}^{\infty} f_i(x).\, f_s(x-X).\, dx,$$

$$S*K=\int_{-\infty}^{\infty} f_s(x).\, f_K(x-X).\, dx, \text{ and}$$

$$K*I=\int_{-\infty}^{\infty} f_k(x).\, f_i(x-X).\, dx$$

The convolution between all the three capitals is given by

$$I*S*K=\int_{-\infty}^{\infty}\left[\int_{-\infty}^{\infty} f_i(x).\, f_s(x-X).\, dx\right].\, f_K(x-X).\, dx$$

The Criteria for the three Knowledge Capital, Social Capital and the Infrastructure Capital to diffuse completely (Innovators, where $0<\zeta<<1$) is that $I*S= S*K= K*I= I*S*K$.

That is:

$$\int_{-\infty}^{\infty} f_i(x).\, f_s(x-X).\, dx, = \int_{-\infty}^{\infty} f_s(x).\, f_K(x-X).\, dx = \int_{-\infty}^{\infty} f_k(x).\, f_i(x-X).\, dx = \int_{-\infty}^{\infty}\left[\int_{-\infty}^{\infty} f_i(x).\, f_s(x-X).\, dx\right].\, f_K(x-X).\, dx$$

Index of Knowledge Diffusion KD_i is defined as the ratio of convoluted Area that is the area formed by diffusion to the Sum total of individual areas. Thus KD_i is given by:

$$\int_{-\infty}^{\infty}\left[\left\{\int_{-\infty}^{\infty} f_i(x).\, f_s(x-X).\, dx\right\}.\, f_K(x-X).\, dx\right] / \left[\int_{-\infty}^{\infty} f_i(x).dx + \int_{-\infty}^{\infty} f_s(x).dx + \int_{-\infty}^{\infty} f_k(x).dx\right]$$

The value of KD_i *ranges between 0 and 1. At* $KD_i = 0$ *and 1.* For these extreme cases values of $g_{1,2}$ and $g_{2,1}$ would respectively be:

$(g)_{1,2} = K_1$, $(g)_{2,1} = K_2$ *and*

$(g)_{1,2} = (g)_{2,1} = K_1 + K_2$

The total knowledge in an organization (comprising of 2 strata) for $KDi = 0$ *is*

$G = K_1 + K_2$

The total knowledge in an organization (comprising of 2 strata) for $KDi = 1$ *is*

[7] A convolution is an integral that expresses the amount of one function has shifted over another. It therefore blends one function into another (Bracewell, 1999; and Hirschman and Widder, 1955)

$G=2(K_1+K_2)$

For an organization with maximum diffusion between Knowledge Capital, Social Capital and Infrastructure capital, the value of KD_i is 1. This means there is no impediments to organizational level communication, free flow of knowledge through free movements of knowledge carriers (*KC*). This is the case when the Viscosity is low and the damping ratio, ζ where $0<\zeta, <<1$. It can be inferred that the value of this KD_i is inversely proportional to the damping ratio ζ, and organizational viscosity, η.

Interpretation of kD_i with respect to type of organizations

In their work, Millar and Langdon (1998) specified a graph consisting of an innovation curve and a clarity curve (figure 7). The x-axis represents time (t) and y-axis represents payoff (p).

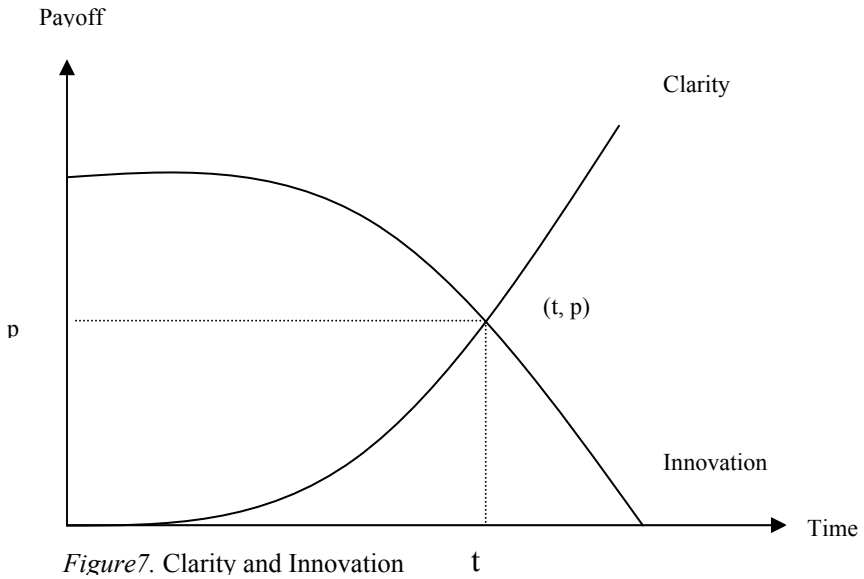

Figure7. Clarity and Innovation

It can be logically inferred that the intersection points *(t, p)* of the two curves is where an organization can understand the benefits from the innovation. For a lesser value of *t*, the value of *p* increases making the organization more innovative.

With the increasing level value of D_i (*max =1*) the value of *t* decreases and that of *p* increases. So for an *Innovator* ($D_i \approx 1$) organization the curves meet at a point that has a very high value of *p* and an extreme low value for *t*. For *adapters* (*early to late*) the value of D_i significantly

decreases, lowering the payoff, p while increasing the time, t. For *laggards* and *virtual innovators*[*] $D_i \approx 0$. This information is summarized in figure 8.

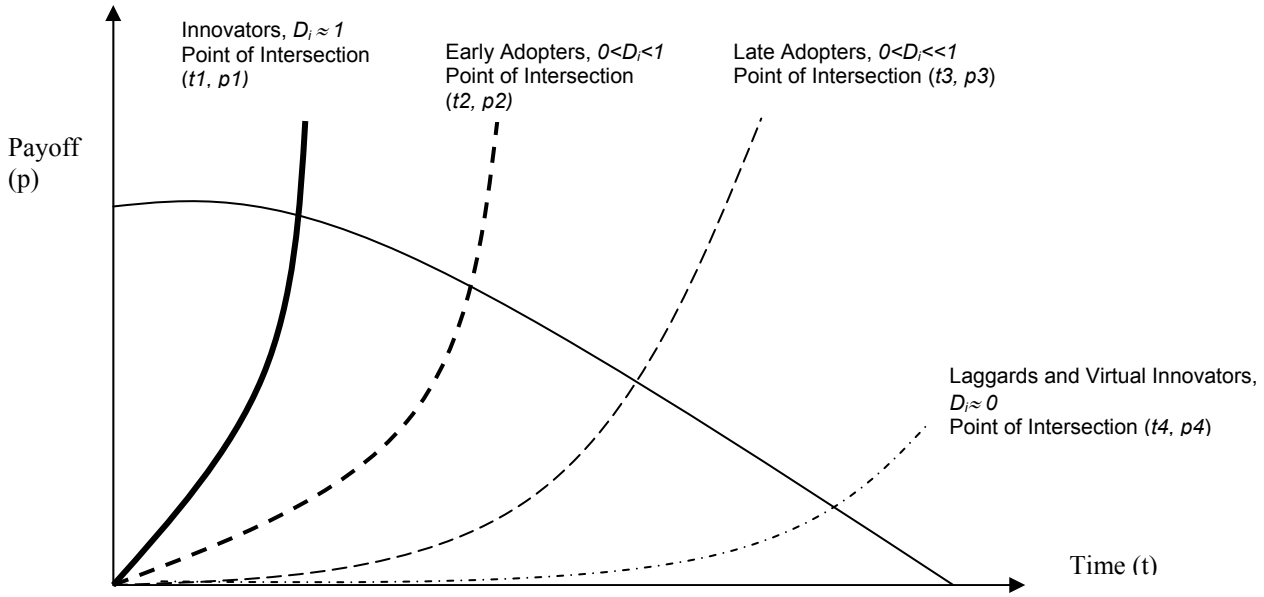

Figure 8. Clarity and Innovation for the types of organizations

Based on figure 8 it can be concluded that with increase in the value of D_i the value of t decreases from Innovators to Virtual Innovators and Laggards ($t1 < t2 < t3 < t4$), while the value of p increases from Innovators to Virtual Innovators and Laggards ($p1 > p2 > p3 > p4$).

4. CONCLUSION AND RECOMMENDATIONS

In order to stay competitive in a discontinuously changing environment, an organization must facilitate a culture that encourages diffusion of knowledge. This cannot happen unless the organization breaks its functional boundaries, and dissolve the differences among the layers of management. A flattened organization, with thin boundaries between the strategic business units is ideal to stay competitive. Such an organization minimizes the probability of destructive conflict of interest and reduces organizational viscosity. Lower organizational viscosity results in lowering the damping ratio. A low damping ratio either makes an organization an *Innovator* or an

[*] For *Laggards* the rigidity of organizational structure impedes the integration of the three capitals thereby hinders the Diffusion of knowledge, there by lowering the value of $\boldsymbol{D_I}$
For *virtual innovators* however there is no social infrastructure per say, so integration cannot make up any useful knowledge diffusion.

early *Adapter*. While the former determines the steady level of competitive advantage, the later quickly adapts itself to reach that level defined by the innovator. With the increasing value of damping ratio reduces the organizational agility to renew itself against the volatile environment, making an organization either late adapters or laggards. It was also shown that a minimal level of damping, through feedback mechanism is also required for an organization to stay competitive, otherwise the organization becomes a virtual innovator, generating great ideas but no process of implementations.

Role played by the organization in promoting knowledge diffusion is very crucial. First of all, the management of an organization should appreciate the relevance of knowledge as a tool to carry out organizational transformation and making it flexible and responsive to remain competitive in an ever-changing business environment. Secondly, the management should provide resources to create infrastructure to support efforts to acquire, assimilate and propagate knowledge throughout the organization. Thirdly, it is responsible for the organizational structure, distribution of power, organizational culture, quality of communication etc, which when taken together have significant contributions on how effectively can knowledge percolate in that organization. Knowledge cannot be created or diffused in an organization that impedes free interaction among employees. Fourthly, promotion of free movements of KC encourages employees to take knowledge initiatives, which in turn will increase *the ratio of total employees to innovators* (Hamel and Getz, 2004), which is important for an organization to stay competitive. In all the above factors, the common issue is how much flexibility or maneuverability and motivation the organization provides to the knowledge persons, the prime movers of any knowledge based and knowledge supported activities.

5. FUTURE RESEARCH

In future research, it will be shown how organizations remain competitive when the steady state also changes with time. The steady state as showed here is representative of a snapshot of a particular time frame. Longitudinally the steady state also changes with respect to time, representing a polynomial function of time and some organizational parameters. The show our formulations depicted in this paper remain stable after such considerations.

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